CHARACTERIZATION OF NICKEL-HYDROGEN 2-Cell COMMON PRESSURE VESSELS FOR NASA MISSIONS

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ABSTRACT

Cells from the flight lot of The Mars Global Surveyor (MGS) battery were configured as a test pack and underwent characterization tests. The MGS battery is based on 20 Ampere-hour 2-Cell Common Pressure Vessel (CPV) technology. The primary goal of the current CPV characterization test was to understand how (NiH_2) V/T curves would map onto the NiCd curves existing in spacecraft hardware. To that end, (NiH_2) V/T curves were experimentally determined. The results of that determination are described below.

INTRODUCTION

Nickel-Hydrogen (NiH_2) batteries have been used on communication satellites for many years, but until recently the Hubble Space Telescope was the only NASA mission that utilized NiH_2 technology. During the coming years several more NASA missions will use Nickel-Hydrogen batteries as the means of energy storage. Many of these missions have baselined the newer 2-Cell Common Pressure vessel (CPV) technology. The Mars Global Surveyor (MGS), which was launched last November, was the first of these missions. Other near term missions such as SSTl-Lewis, Mars Surveyor Program (MSP'98), MIDEX, and Stardust have built or are in the process of building tight batteries also based on the more recent CPV technology.

Charge control for spacecraft NiH_2 batteries has evolved for optimum maintenance of batteries for satellites in Geosynchronous (GEO) orbits. For these types of orbits, there is one charge/discharge cycle per day and hence a relatively longer time for charging. The usual charge control method consists of charging the battery to a fixed charge to discharge ampere-hour ratio (C/D ratio) at a relatively high rate (C/1O to C/25) and then switching to a trickle charge rate (C/60 to C/100) for the remainder of the 24-hour eclipse day (Dunlop et. al., 1993). The actual vafues of the C/D ratio and the time spent on trickle charge area function of temperature. The actual charge and discharge rates and are governed by experience.

In the case of Low Earth Orbit (LEO) spacecraft, batteries undergo on the order of 15 charge/discharge cycles per 24 hour period and hence the batteries have only about 60 min. to be fully charged before the next discharge cycle begins. Charge control schemes similar to those used on for GEO spacecraft have been successfully used in LEO ground tests of $N1H_2$ batteries. Values of the charge control parameters (rates, C/D) for these tests are again judicious choices based on experience. The goal of charge control schemes is to bring the batteries to the highest possible state of charge while minimizing overcharge. Minimizing overcharge is generally accepted to reduce &gradation and increase cycle life, especially in LEO regimes, this was a major reason for the development of NiCd V/T curves.

In the case of MGS, the hardware for charge control was inherited from a previous mission which was based on NiCd V/T curves. The potential use of flight hardware designed for a NiCd system used to control a NiH_2 battery was the main driver for the characterization tests described below.

EXPERIMENTAL

The test article was a three unit pack of RNHC-20-7 Common Pressure Vessel Cell (CPV) from the MGS flightlot manufactured by **Eagle-Picher** Industries. **The** salient features of the design include: Nominal capacity 20 Ah, **EPI Mantech** design, 'Rabbit' ear terminals double layer Zircar **separator, Zirconium wall wick,** Teflon barrier on weld ring, Nickel precharged, 31 %KOH, with a nominal weight of 1260g/CPV. The three cell pack was wired for computer control and monitoring and placed **in a temperature** controlled chamber. The initial test sequence included a partial sequence from the Acceptance Test procedure performed at the manufacturers facility before shipment (10"C capacity, 25°C capacity, -5°C capacity and charge retention).

The steps for determination of V/T curves have been previously described (Ratnakumar et. at., 1996) and are summarized as follows:
a) Select typical orbital profile (120 min. orbit with 41 min. discharge).
b) Select Charge Discharge rates expected for the mission (9.6 Amp discharge, 7.5 Amp charge in the case of MGS).
c) Set chamber temperature and soak the pack until temperature is stable.
d) Select initial voltage limit level and cycle cell **until** stable State of Charge is obtained (60 cycles)
e) Perform a capacity check (C/2 discharge to 2.0 V/CPV followed by a C/10 charge for 16 hours)
f) Increase voltage limit and repeat steps a to e until enough points are taken to determine the trend.
g) **Select** a new temperature and perform steps a to f.

The above sequence generates a family of curves one for each temperature (Voltage vs % Recharge) from which the V/T curves can be constructed. The curves are constructed by selecting a safe ' % Recharge' operationat range based on previous experience. The corresponding voltage range is subsequentl y divided into 16 segments **which define the** V/T levels. Details of the V/T **curve construction are** presented **in the results and discussion section.**

RESULTS AND DISCUSSION

As described above, **initial evaluation of the** cells included **partial replication** of **the ATP test performed at the** manufacture's facility. Results of the 10°C capacity tests **arc shown if Figure 1.**

Figure 2 is a typical equilibration cycle under expected typical orbital conditions as described in the figure. After the state of charge is stabilized (60 cycles) the '% Recharge' or C/D ratio was obtained. This sequence was performed as a function of temperature and voltage as described in steps a to g. Furthermore, after the 60th cycle at each of these conditions, once the cells had stabilized, a capacity measurement (i.e. C/2 discharge) was performed before going on to the next set of sixty cycles. The results of the stabilized capacity measurements are shown in Figure 3 as a family of curves which show C/D ratios a function of voltage at different temipratures. V/T curves can be determined from this figure by selecting an acceptable range of C/D ratio, this selection is usually based on experience. An appropriate selection is to chose the range of C/D ratio from 101% to 120%. This selection defines the voltage range from 1.46 V to 1.52 V per cell. In this case there are 16 cells (8 CPVS per battery) thus the battery voltage range would be from 23.4 V to 24.3 V. In practice, **however, end of life performance is** characterized by an increase in cell impedance and a provision has to be made to be able to charge at higher voltages at the end of life. Similarly provisions need to be made to be able to charge the battery with one cell shorted.

Figure 4 shows the experimentally obtained V/T curves (V/T exp) **superimposed on the actual V/T** curves **(V/T1** to V/T8-S) which reside in spacecraft hardware. The spacecraft V/T curves were originally developed for a NiCd battery by a technique similar to the one described in the text, subsequently they were shifted down by - 1.0 V in anticipation of being able to charge a NiH_2 battery. The symmetry and spacing of the spacecraft V/T curves is a direct consequence of the electronics used to generate them. Superposition of the experimentally determined V/T curves indicate that the spacecraft V/T curves will satisfy the conditions mentioned above and **will be sufficient to charge the MGS** battery.

Figure 5 shows the state of charge (C/2 capacity at the end of the 60th cycle under the given conditions) as a function of voltage. The data corroborate the indication that it will be difficult [o fully charge the battery if it warms up to ~20°C. From the figure it can also be seen that going to voltage levels greater than 24 V (1.5 V/cell) will not result in any additional capacity unless the battery is at very low temperatures. Figure 5 can also be used as a guideline to select the optimum V/T level to maintain energy balance and minimize overcharge.
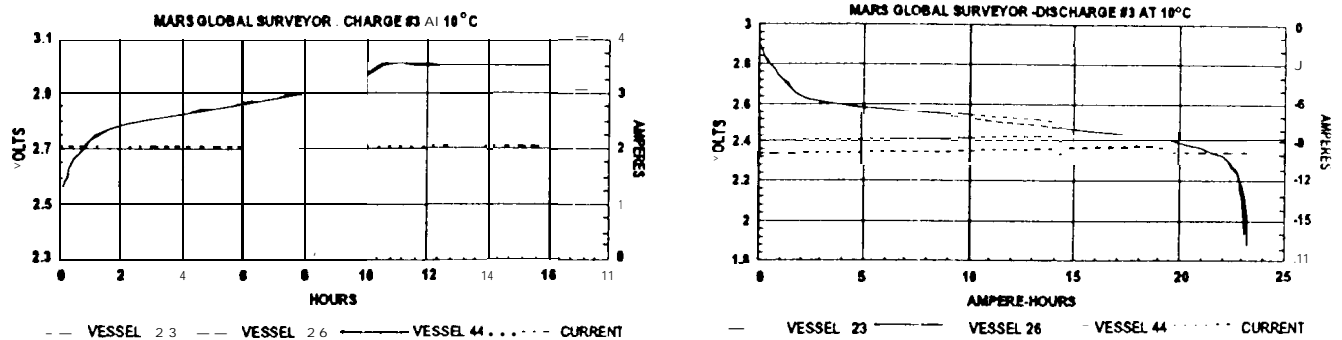
Figure 1. C/10 charge followed by C/2 discharge on a three cell pack of 20 Ah NiH$_2$ 2-cell CPV units from MGS lot.
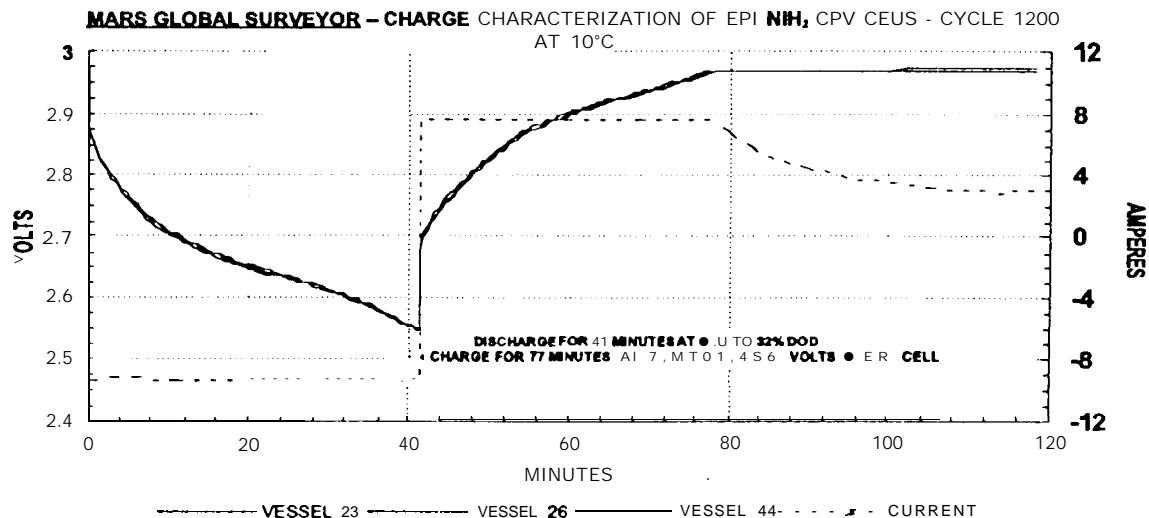

Figure 2. Typical cycle, one of 60, characteristic of the Mars Mapping orbits for which the battery will be charged using V/T control.
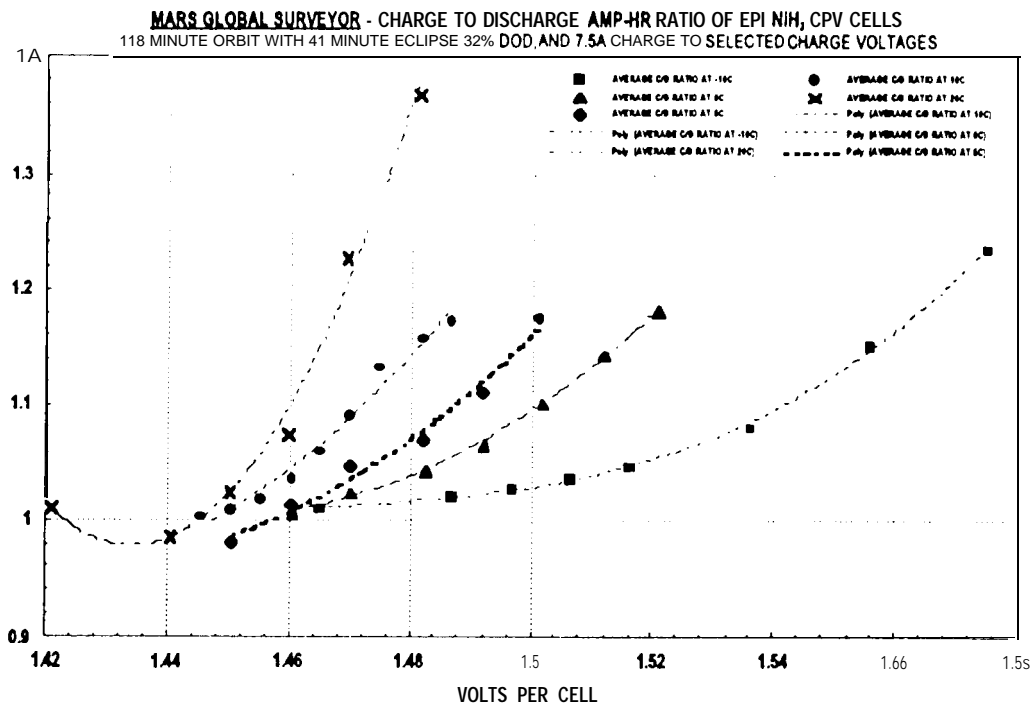
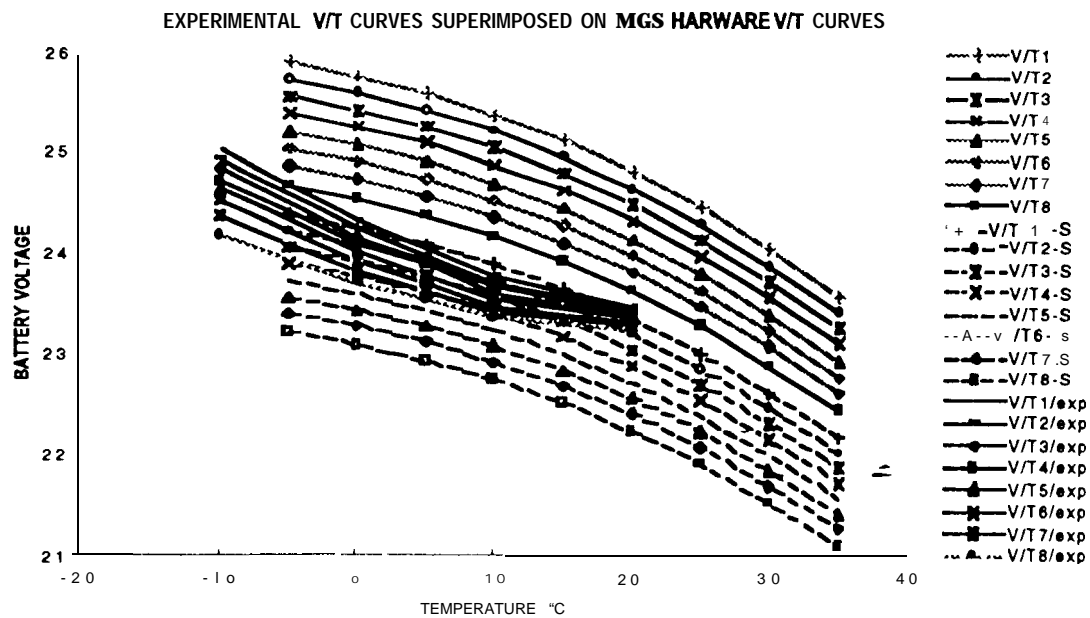**Figure 3.** **Charge to discharge ampere-hour ratio as a function of temperature and charge voltage.**

EXPERIMENTAL V/T CURVES SUPERIMPOSED ON MGS HARWARE V/T CURVES

Figure 4. **Experimental curves superimposed on hardware curves.**

MARS GLOBAL SURVEYOR - C/2 DISCHARGE CAPACITY OF EPI NiH₂ CPV CELLS
118 MINUTE ORBIT WITH 41 MINUTE ECLIPSE, 32% DOD, AND 7.5A CHARGE TO SELECTED CHARGE VOLTAGES
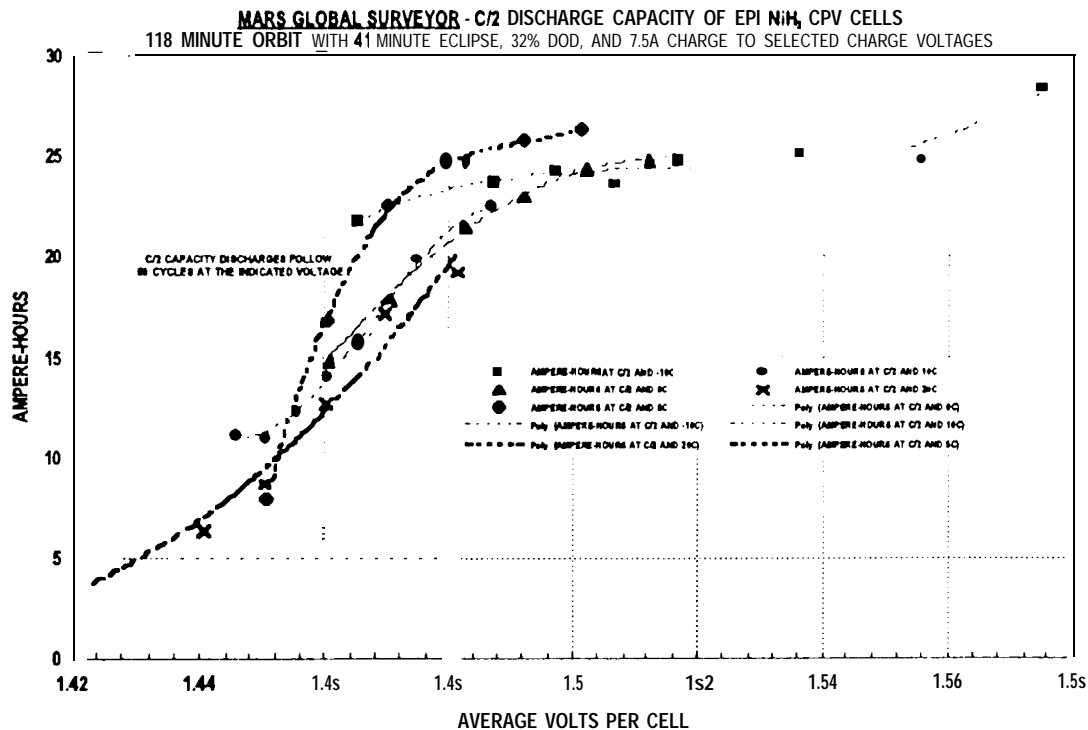

Figure 5. State of charge as a function of temperature and voltage.

SUMMARY

A three cell pack of RNHC-20-7 CPVS from the MGS flight lot were characterized to determine Use feasibility of charging the MGS battery with V/T curves inherited in hardware. The characterization tests show that the spacecraft V/T curves are sufficient to charge the battery. The characterization data also indicate that charging the battery to voltages above 1.5 V cell would not add any capacity to the battery unless the battery was at a very low temperature. The Voltage vs. state of charge can be used as a guideline for the selection of the optimum V/T level.

REFERENCES

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